AERONAUTICS.

INTERIM REPORT

OF THE

ADVISORY COMMITTEE FOR AERONAUTICS

ON THE

WORK FOR THE YEAR 1910-11.

Presented to both Houses of Parliament by Command of His Majesty.

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CONTENTS.

ADVISORY COMMITTEE FOR AERONAUTICS.

To the Right Honourable H. H. Asquith, M.P., First Lord of the Treasury.

Sir,

The Report of the Advisory Committee for Aeronautics for the year 1909–10 was prepared in April last, and was presented to Parliament on July 25. Since the date of the preparation of that Report a large amount of experimental work has been carried out, and it is thought that a short account of the progress made and the results obtained may be of interest.

Equipment for experimental work.—A general description of the equipment which has been provided at the National Physical Laboratory was given in the Report for 1909–10. The erection of the necessary buildings and the construction of the apparatus occupied the greater part of the year covered by that Report. Modifications in detail which have since been made in some of this apparatus are mentioned below. The equipment installed has proved in general satisfactory for the purposes for which it was provided.

Wind channel.—This has been improved by the addition of guide planes and honeycombs to secure greater uniformity of flow in the air current. It is necessary for rapidity and accuracy of working that the flow should be uniform across a section of the channel and also that the flow past any point should not exhibit any pulsation; further, this uniformity both in space and time must be maintained for all speeds of the air current at which it is desired to experiment. The problem of securing a completely satisfactory flow under all the varying conditions of experimental practice has received much attention, and the experience gained will be of great value in the future construction of wind channel apparatus for experimental work.

The special apparatus designed and constructed at the Laboratory for the simultaneous measurement of the air resistances, parallel and perpendicular to the direction of the current, of the model under test has proved very convenient in working. As previously described, the design includes an arrangement enabling the model to be rotated readily between each set of measurements, so that the "lift" and "drift" at various angles can be very rapidly determined.

The results of some of the earlier experiments in the air channel are given in the Report for 1909–10. A large number of investigations have since been made to obtain the information necessary in connection with the constructional work proceeding at Farnborough and Barrow. For some of these investigations the water channel has again proved very useful, valuable information being thus obtained from quite small models to supplement the work done

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in the air channel. Among the researches carried out may be mentioned specially the determination of the magnitudes of the forces on airship bodies, of different forms, inclined to the wind, and the line of action of the resultant force in each case; the determination of the relative efficiency of different types of rudders and lifting planes; the investigation of the resistance of model gondolas, and also of models of radiators, and of wires, stays, &c. An important series of experiments has also been made to investigate the forces due to the wind on dirigible sheds. These experiments were all undertaken at the request of the Constructive Departments as a guide in designing, and the designs adopted have been based on these experiments. It is hoped to embody particulars of those results of this work which are of general interest in the Report for 1910–11.

Whirling table.—Some modifications have been made in the apparatus for determining the thrust and torque of a propeller in motion, to secure greater sensitiveness and range in the measurements. It has been found, further, that at high propeller speeds the whirling arm, which can be driven independently of the propeller, rotates under the action of the propeller alone more rapidly than is sometimes desired, and a braking apparatus has accordingly been added. An additional motor is also being provided so that propeller speeds up to 4,000 revolutions per minute can be attained.

In conjunction with Messrs. Vickers, Sons, & Maxim, who have kindly undertaken to place at the disposal of the Committee the results of tests of propellers made on the large whirling table they have erected at Barrow, a series of tests is in progress to determine the dimensional coefficient, a knowledge of which will, it is hoped, enable the efficiency and characteristics of a full-sized propeller of given form to be predicted from experiments on small scale models. This investigation, which is of fundamental importance, will demand the continuous use of the Laboratory whirling table, possibly for some months.

A large number of requests for tests on propellers have been received from private firms and individuals. Arrangements have been made for carrying out such tests, so far as may be possible without interference with the work required for the Constructive Departments, and the investigation to which reference is made above. A short statement as to the conditions appertaining to such tests is given in Appendix 1.

A number of experiments with model propellers of simple form have been made. Tests of model propellers have also been carried out for the Superintendent of the Balloon Factory.

Wind Towers.—The wind towers were completed early in the spring, and the investigation on wind structure which had been planned has since been continuously in progress. To obtain further information as to variations in the wind velocity within the whole area between the two main towers, which are 330 feet apart, lighter towers have been constructed, to be set up between the two already erected, and these are now ready to be put in position. Special apparatus has also been designed and constructed for recording the mean wind pressure at a number of points within the area. The records so obtained will give valuable information as to the

variations in wind velocity to be expected within a fairly large area, information which is necessary to enable the effect of the wind on a large surface to be estimated with any high degree of accuracy.

The arrangements for open air experiments on large models have also been completed, and tests will be made for comparison with the results obtained on smaller models in the wind channel.

Tests on Motors for Aeronautical Purposes.—The apparatus for tests on motors up to 50 H.P., the design of which was described in the Report for 1909–10, has now been installed. It has been placed in the extension of the Engineering Building at the National Physical Laboratory provided to give space for the aeronautical work, the building having been designed to allow of the special features necessary.

The equipment has proved very satisfactory in use. It has been employed in testing the engines entered for the Alexander Prize Competition, and has thus itself been subjected to a sufficiently severe test.

Alexander Motor Prize Competition.—Six engines were originally entered for this competition, of which three only were delivered at the Laboratory by the date specified by the Committee, viz., July 1st, 1910. These three engines were submitted by the following firms :—

Green's Motor Patents Syndicate, Ltd.
Humber, Ltd.
The Wolseley Tool and Motor Car Co., Ltd.

The tests on these three engines have been completed, and the Committee have made a report to the Aerial League on the results of the tests. This is printed as an Appendix to the present Report.

Balloon Fabrics.—Strength Tests.—Tests have now been carried out on a large number of balloon fabrics. Information of considerable importance has been obtained, and the work is being continued with a view to publishing later a complete account of the results. Several series of tests on specially selected fabrics have been made at the desire of the Constructive Departments, to whom the results have been of value in the choice of suitable materials.

In connection with the strength tests, investigations have been made to determine the effect of the rate of loading, and the effect of repetition of stress. The apparatus employed has been supplemented by a testing machine by Messrs. Avery; this is being modified to enable rates of loading varying from 50 to 1,200 kgs. per minute to be employed. Some further work is being done with a view to determining the form of tensile test which gives the most useful information to the designer. For the ordinary comparative tests of samples of fabric, specimens of the usual dimensions, 20 cm. between the jaws of the testing machine by 5 cm. in width, are now generally employed, and the usual rate of loading is such as to fracture the specimen in not less than two minutes.

The bursting tests on cylinders of fabric have been continued, but considerable difficulty was at first experienced in obtaining a

satisfactory join. Cylinders have now been procured in which the join is not less strong than the plain fabric, and a bursting test of one such cylinder gave high values for the ultimate stresses. Some damage was done to the apparatus in this test, and the apparatus has now been reconstructed and the tests are being proceeded with.

A system of tests of strength to resist tearing has been designed, and this work is now in progress.

Permeability Tests.—The apparatus employed for permeability tests was fully described in last year's report. Some minor modifications have been made, but the apparatus has proved generally very satisfactory in working. Permeability tests have been carried out on a variety of fabrics, including rubbered fabrics by different makers, proofed silks and cotton, goldbeaters' skin and paper. Some of the figures obtained were published in the Report for 1909–10. In the rubbered fabrics the capacity for holding hydrogen seems to be generally dependent on the weight of rubber in the fabric. It is possible that diagonally doubled rubbered fabrics are superior to parallel doubled, but this cannot be definitely asserted without further investigation. Some samples of proofed silk tested have shown a hydrogen containing capacity equal to that of the best and heaviest rubbered cloths, with a greatly lower weight. The excellence of goldbeaters' skin in this respect was shown by the figures previously published. Paper, sized and unsized, has been tested, but hydrogen passes through it with great readiness.

Some tests have been made to determine the variation in permeability with rise of temperature. The rubbered fabrics tested have shown a somewhat rapid increase of permeability, while a proofed silk gave a slightly lower permeability at the higher temperature. The permeability of goldbeaters' skin was found to increase slightly with temperature rise. The effect of low temperatures will also be investigated.

Other Tests of Fabrics.—Durability tests have been made by exposure of samples in the open to sun and weather. After weathering, the samples are subjected to tensile and permeability tests. After an exposure of fifty days proofed silk and rubbered cotton fabrics showed a loss of strength not very different in amount in the two materials. The permeability of the rubbered fabrics, however, very greatly increased, while some of the samples of proofed silk showed actually a decreased permeability. One sample of proofed silk taken down for test on a cold day showed a permeability much larger than that of the other samples, probably due to crumpling at a somewhat low temperature; when re-exposed in the sun the permeability of this again decreased. Goldbeaters' skin deteriorated considerably with exposure both in strength aud hydrogen holding capacity.

Tests of rubbered fabrics have also been made under exposure to ultra-violet light, and deterioration observed. The tests are being continued, and the effect of protective colouring is being investigated.

Tests to determine the amount of moisture absorbed by fabrics

under different conditions have also been made, and have given useful information. The tests are included in the series of tests now usually applied to fabrics which are being subjected to a thorough examination.

All the above tests will be repeated on the best of the rubbered fabrics previously examined, and on other promising materials such as the proofed silk which has been referred to, and it is hoped that the figures obtained in these and the earlier tests may be included in a full account of the work done on fabrics to be issued later.

Meteorological Research.—For the further study of wind structure researches have been undertaken at Pyrton Hill, Oxfordshire, by Mr. J. S. Dines, with a mechanical assistant, under the direction of the Meteorological Office. The locality has been selected because the work can be carried out there in conjunction with the investigation of the upper air for the Meteorological Office, which is in charge of Mr. W. H. Dines, F.R.S.

The immediate object of the researches is to find out, by means of careful examination of instrumental records of various kinds, how far up the ordinary gustiness of wind extends, to trace whatever evidence can be obtained of vertical motion or rotary motion in the atmosphere, and to identify the conditions in which such motion exists.

In order to test for gustiness above the surface, apparatus has been designed which registers simultaneously the pull of a kite wire, with the fluctuations therein due to gusts, and the length of wire paid out. From the latter, with a knowledge of the vertical angle, the height of the kite can be approximately determined. A few records have been obtained, and in these the diminution of gustiness with height is clearly apparent.

For the identification of rotary motion a new model of the Dines pressure tube anemograph has been constructed to record both direction and velocity upon the same drum—an indispensable requirement. The recording part has also been remodelled in order that the trace may represent the combinations of variation of velocity with that of direction. The apparatus is completed and works well. It has been erected with the vane at a height of 35 feet above the ground, to begin with. A considerable number of diagrams have been obtained from it, mostly for light winds. The fluctuations as recorded show, for the most part, little trace of the combination of variations in velocity and direction which would correspond with rotary motion ; changes in velocity and direction take place independently and spasmodically, but in a few cases the sequence of changes is more orderly. No doubt much depends upon the character of the locality and the type of weather. Working drawings have been made of the essential parts of the apparatus so that corresponding observations can be set on foot elsewhere for the study of the effect of locality.

For the study of vertical motion, self-recording gear has been designed to be fitted to a theodolite so that a single observer can attend to the instrument and obtain a record of the variations of the azimuth and altitude of a pilot balloon. With two such theodolites the path of the balloon can thus be determined both as regards its horizontal and its vertical motion. Two instruments

have been constructed, both of which work well, and balloons have been followed by them to heights of about 2,500 feet. The balloons used in these experiments have been toy balloons costing only 6*d.* and 1*s.* respectively. The possibility of following successfully the flight of these small balloons makes this important mode of observation available for many useful aeronautical purposes at very reasonable cost. The second theodolite has only recently been completed, and only a few ascents have been observed. One of these shows remarkable variations in the vertical velocity of the balloon, which can only be attributed to variations as regards vertical motion in the air currents traversed by the balloon. The results are in every way satisfactory.

The instrumental equipment for the researches contemplated is now practically completed. As regards plant and installation, what are now required are means for exposing the various instruments at suitable heights. This part of the work will be proceeded with as soon as a sufficient number of observations at the present trial levels have been obtained.

Advice on other matters.—The advice of the Committee has also been sought by the Constructive Departments on various matters in which experimental investigation was, in general, not necessary. Among these may be mentioned the following :—

(i) Recovery of hydrogen from a mixture of hydrogen and air.
(ii) Methods of damping the vibrations of pressure gauges and other instruments carried on a dirigible.
(iii) Methods of supporting the engine on a dirigible so that its vibrations shall not be transmitted to the chassis.
(iv) Effect of corrugations in the gas-bag on the air resistance.
(v) Variations in pressure over the envelope of an airship.
(vi) Stress due to air pressure on sudden stoppage of an airship, by anchoring or otherwise.
(vii) Methods for determination of the horizontal in an airship.

On these and other questions submitted to them the Committee has been able to give assistance.

Reports and Memoranda.—The series of reports and memoranda, of which a number were printed as appendices to the Report for 1909–10, has been continued, and those of general interest will be prepared later for publication. The report by Sir G. Greenhill on the "Theory of a stream-line past a plane barrier and of the discontinuity at the edge, with an application of the theory to an aeroplane," has now been completed and is ready for issue. The aim of this report has been to collect for reference the chief results in the theory of discontinuous fluid motion, so far as it has been carried at present, with extensions, such as those on vortex motion, likely to be useful in artificial flight.

The abstracts of technical papers on aeronautical questions have also been continued, and these will be printed in the report on the work of the current year.

Signed on behalf of the Committee,

RAYLEIGH,

President.

APPENDIX 1.

Conditions for tests of model propellers.

The National Physical Laboratory.

Engineering Department.

Efficiency tests on model propellers up to 2 ft. 6 in. in diameter can now be undertaken in the Aeronautics Division. The diameter preferred is 2 ft. The boss should be left solid, and should have an axial length of not more than $1\frac{1}{2}$ in. Right-handed propellers are preferred.

Up to the present time provision has only been made for propeller speeds up to 1,800 r.p.m., and driving power up to $\frac{1}{2}$ H.P. Provision is being made for testing propellers at higher speeds, and the necessary equipment is now nearly completed. The following will be the limiting conditions :—

Propeller speed not greater than 4,000 r.p.m.
Propeller torque not greater than 20 inch-lbs.
Speed of translation not greater than 3,000 ft. per minute.

It should be understood that these tests will be undertaken in rotation, and that, while the Department will do all that is possible to avoid undue delay in carrying out the work, tests for the Government Departments must take precedence of all others.

Applicants should state the precise speeds of translation corresponding to the speeds of rotation at which the efficiency is to be determined ; and the fees will depend on the number of such observations required.

November 12th, 1910.

APPENDIX 2.

Alexander Motor Prize Competition.

The question of tests on motors for aeronautical purposes engaged the attention of the Committee at an early date, and in the preliminary programme of work drawn up in June, 1909, were included tests of motors for efficiency and for reliability and steadiness of running. The provision of the necessary equipment for carrying out such tests was at once put in hand, and an investigation into the performance of motors of different types was contemplated.

In the autumn of 1909, Mr. Patrick Y. Alexander made an offer, through the Aerial League, of a prize of £1,000 for the best motor for aeronautical purposes which should satisfy certain conditions, the most important of these being that it should pass a satisfactory endurance test. The Aerial League applied to the Advisory Committee for their assistance, and the Committee replied that they were prepared to co-operate with the League in drawing up the regulations for the Competition, and that they would undertake to carry out the necessary tests on the motors submitted, and to report to the League as to the results.

The regulations were accordingly drawn up in November, 1909, by a Committee consisting of members of the Advisory Committee in conjunction with Mr. Alexander and three representatives of the Aerial League. These regulations are printed below.

The engines were required to be delivered at the National Physical Laboratory not later than July 1st, 1910, and the tests have recently been completed.

The account here given of the arrangements made for the tests, and of the results of the trials, is presented in the following order :—

(i) Regulations.

(ii) Description of the Testing Plant at the National Physical Laboratory.

(iii) Report made to the Aerial League.

(iv) Reproductions of the autographic records of speed and torque during the 24 hours' trials.

(i) Regulations.

General Regulations.

1. *Machine of British Manufacture.*—The machine to be of British manufacture.

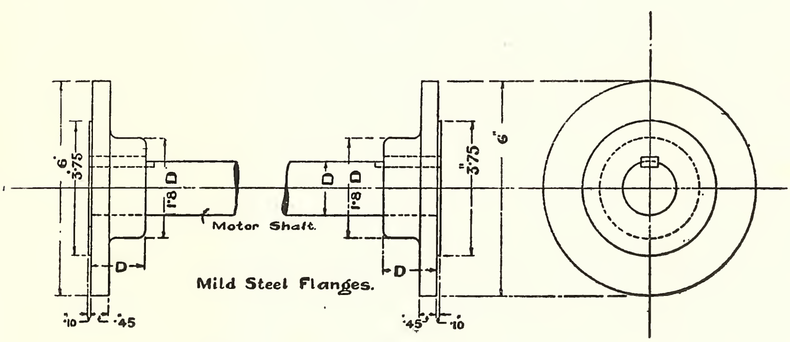
2. *Horse Power.*—The motor to be designed to give 35 B.H.P. The machine will be required to reach this B.H.P. on a preliminary run.

3. *Description.*—The maker to supply a detailed description and drawings, together with a statement of the principal features of the machine. The drawings to show the engine, radiator, tanks, etc. fixed to a known type of aeroplane, so that the length of the connecting pipes can be determined and impossible combinations for trial purposes guarded against.

4. *Limit of Weight.*—Motors weighing more than 245 lbs., that is, 7 lbs. per B.H.P., will not be admitted for competition. For the purposes of this clause the weight shall be taken to include the weight of the motor itself with crank-case and supporting arms, and all parts necessary for ordinary running, also the cooling apparatus with all accessories (clauses 18, 19). It will not include the supply of cooling water, petrol and lubricating oil, or the containing vessels for these.

5. *Couplings to be Provided.*—To enable the motor to be coupled up to a dynamo for the determination of its efficiency, and also for the application of the required end thrust or pull, the motor shaft is to be provided with two half-couplings to the design shown below (Fig. 1.)

Fig. 1.

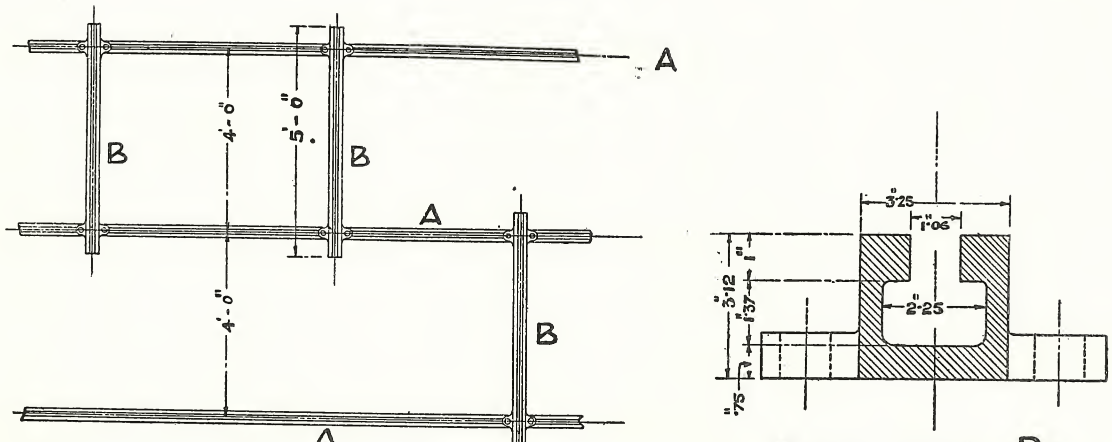


Dimensions of Couplings.

6. *Mounting for Purposes of Test.*—To facilitate the erection of the machine on the testing apparatus, the motor, with radiator, must be mounted so that it can be bolted to the pair of adjustable testing rails shown in Fig. 2 (see next page).

7. *Patents.*—Each competitor to take any steps he may desire to protect his machine by patent.

Fig. 2.



Section through B.

Least height of Centre of Motor shaft above upper surface of Movable Rail = 16·13 inches.

A Fixed Rails.
B . Movable Rails.

Arrangement of Support for Motor Testing.

8. *Price.*—The price to be stated, and the first option for the purchase of the machine at the price at which it is entered, to rest with the Advisory Committee until the report on the tests is issued.

9. *Acceptance of Regulations.*—Every Competitor and his representatives, mechanics, or other employees shall be considered to be acquainted with these regulations and by entering undertakes to abide without dispute by all the conditions therein contained, and by any regulations which may be hereafter issued by the Committee or their authorized representative, and by the results to which such rules and regulations may lead.

10. *Committee's Decision Final.*—In the event of any point arising under, or which is not covered by, these regulations, the Committee shall have power to decide upon the same and its decision shall be final and shall *ipso facto* become a regulation of the trials.

11. *Interpretation of Regulations.*—The interpretation of these regulations or of any to be hereafter issued shall rest entirely with the Committee, which may at its discretion waive, alter, add to, or omit from any or all of them from time to time.

If any disputes shall arise in connection with these regulations or with any that are hereafter issued, or with the trial, the decision of the Committee shall be final and binding.

12. *Maker Responsible.*—It is one of the conditions upon which entries are accepted by the Committee that the Committee shall not be responsible for any damage which may be done to or by the engine entered or its appurtenances, either during the trial or while it is under the charge of the Committee, either by fire, accident or otherwise, nor for the theft of the engine or any of its accessories or appurtenances. The engine and its accessories or appurtenances shall at all times be at the risks in all respects of the entrants, who shall be deemed by entering to indemnify the Committee against all legal proceedings, costs or penalties whatsoever relating to or arising out of the trials.

13. *Damage.*—Any damage caused by any maker or his representative, mechanic, or other employee, at any time, whether before, during, or after the trial, shall be paid for by such entrant. The Committee is hereby irrevocably authorised as agent for any such maker to settle and agree the amount of any such damage, and to pay the amount thereof, and any such maker shall on demand repay to the Committee any sums which may be disbursed by the Committee in respect of any such damage.

14. *No Claim against Committee.*—Every maker by entering any engine for the trial waives any right of action against the Committee, the Aerial League, or any judge or employee of the League or of the Committee for any damage sustained by him in consequence of any act or omission on the part of the League, Committee, or of their members or representatives or servants, whether with respect to these regulations or to any regulations to be hereafter issued, or to any matters arising therefrom, or any matter arising out of or in connection with the tests.

15. *Makers' Servants.*—The maker submitting an engine for test shall be responsible for all acts or omissions on the part of his representative, mechanic, or other employee, but both the maker and his representative, mechanic, or other employee shall be equally responsible for any infraction of these regulations.

16. *Insurance.*—The maker shall insure his employees against damage by accident during the course of the trial or while they are on the premises in which the trials are held.

Conditions of Test.

17. The main points which will be considered in the comparison of motors admitted for competition will be :—

A. Weight and consumption of petrol per B.H.P.
B. Reliability and steadiness of running.
C. Wear of working parts.
D. Security against fire.
E. Air resistance offered by the motor and accessories.

A. Weight and Consumption of Petrol per B.H.P.

In the Total Weight, for purposes of comparison, will be reckoned :—

18. The weight of the motor itself with crank case and supporting arms and all parts necessary for ordinary running, as for instance—the carburettor and regulator, the automatic lubricating apparatus, the ignition, together with the necessary accumulators, coils, etc., sufficient for the time of the test, the connecting tubes for the water between the radiator and motor, and the attachments referred to under (29).

19. The cooling apparatus with all accessories, e.g., fans and their gear.

20. The necessary supply of water for the radiator (if the motor is water-cooled), for a six hours' run.

21. The weight of the petrol and lubricating oil for a six hours' run.

22. The weight of the vessels required for the petrol, oil, etc., for a six hours' run. This will be reckoned as a percentage addition to the weight of the materials—10 per cent. for petrol and 20 per cent. for oil. (The petrol and oil vessels must be provided and must be of sufficient content for a 24 hours' run.)

23. The standard coupling flanges.

In the weight of the motor will not be reckoned :—

24. Exhaust boxes and connections.

25. The flywheel, if a flywheel be provided in accordance with clause 38.

26. Any friction clutches and gearing, and also the foundation bolts and any additional brackets necessary for bolting the machine to the testing rails.

27. Constructional parts which serve for the purpose of support of radiator and petrol vessels.

28. The petrol and oil vessels supplied for the 24-hour run, in place of which [as indicated under (22)] a definite percentage will be added in the calculation.

B. Reliability and Steadiness of Running.

29. The motors will be tested on a 24 hours' run. If from any cause during this run a stoppage is necessary, the time and cause of such stoppage will be noted and entered on the record sheet. This time will be included in the 24 hours for which the test lasts. If the number of stoppages exceed three, or if the total time occupied by such stoppages exceed half an hour, the motor is thereby disqualified.

While the motor is running the only adjustments permitted are those which can be made by the lever for the ignition and carburettor. The handling of the motor for any other purpose, e.g., oiling by hand, is not allowed.

30. Attention will be paid to the balance of the moving parts and to freedom from vibration of the frame of the motor when under test.

31. After the endurance test the machine will be placed on elastic supports and run at different speeds to determine whether any periodic disturbance of a dangerous character is set up.

32. An additional test will be made to determine whether the motor will work satisfactorily when tilted (about an axis transverse to the shaft). Two runs of an hour each will be made at full load at an angle of 15°, first one end and then the other being uppermost.

33. In addition to the above, ease of starting will also be considered.

C. Wear of working parts.

34. After the tests the engine will be dismantled and taken to pieces by the representatives of the makers in the presence of the representatives of the Committee, and a record made of any signs of wear or defect.

D. Security against Fire.

35. The design and construction to be such as to give security against fire. The machine will be examined during and after the tests for any sign of leakage, or of accumulation of petrol on the casing of the engine or elsewhere.

E. Air Resistance offered by the Motor and Accessories.

36. Credit will be given for a design such that the resistance offered to the wind is low.

Further Particulars as to the Tests.

37. *Propeller Thrust.*—The test will be made on the motors alone without propellers, but to represent the thrust or pull of the propeller an artificial thrust or pull of 175 lbs. weight will be applied.

38. *Flywheel.*—For the purposes of the tests the motor may be furnished by the maker with a flywheel having a moment of inertia not exceeding that of a disc, of uniform material and thickness, 2 ft. in diameter, and weighing 75 lbs.

Additional flywheel action is provided in the rotating armature of the dynamometer.

39. *Test under Constant Brake Moment.*—Before the commencement of the tests the maker will be required to declare the speed at which the motor will develop 35 B.H.P. The tests will be made at a constant brake moment calculated from the H.P. and this declared speed.

40. *Record of Test.*—A record will be kept throughout the tests in which will be noted all irregularities of speed and H.P.

Repairs and adjustments made during the 24-hour test will also be recorded in accordance with (29).

The record will also note the general behaviour of the motor and its condition after the completion of the test.

41. *Test Made in Air Current.*—The tests will be made in an air current delivered with a velocity of approximately 30 miles an hour from a horizontal trunk, 4 ft. by 4 ft. in section. The mouth of the trunk will be at a distance of about 6 ft. in front of the motor.

42. *Maximum H.P.*—A test will be made to determine the maximum B.H.P., defined as the highest B.H.P. maintained by the motor for seven minutes continuously.

43. *Gyroscopic Action of the Propeller in Steering.*—A test will be made to determine the effect of the gyroscopic action of the propeller in steering. To represent this action a couple of 50 ft. lbs., in a vertical plane, will be applied to the motor shaft for three minutes while the machine is running, and the effect on the speed and brake moment noted. During this test no adjustment of the motor will be allowed.

44. *Additional Tests.*—Such additional tests and measurements will be made as may appear to the Committee to be necessary for the purposes of the competition.

45. *Superintendence of Engine while under Test.*—The makers will be required to set up the engine. They will also be required to arrange for the superintendence of its working during the tests. Two men will be necessary in order that one or the other may be present during the whole of the 24 hours' run. In addition to these two only one representative of the makers will be permitted to be present on any one day.

46. *Preliminary Runs.*—Preliminary runs will be allowed during one day before the actual tests commence in order to get the engine into satisfactory working condition.

The time at which the 24 hours' test is to commence will be fixed by arrangement with the competitor. A run will be permitted immediately in advance of the time so fixed in order that steady running conditions may have been reached before the actual trial is begun.

47. *Temperature at which Tests are made.*—The tests will be made at an air temperature in the neighbourhood of 60° F.

48. *Petrol supplied.*—The petrol used must be obtained by the maker at the National Physical Laboratory. A standard petrol will be supplied at the current market price. A sample can be obtained in advance on application to the Director, the National Physical Laboratory, Teddington, Middlesex.

(ii) Description of the Testing Plant.

Under the conditions of the Competition the motors were to be tested with open exhaust, and in an air current moving at approximately 30 miles an hour relative to the engines. The principal test was an endurance test of 24 hours' continuous running at 35 B.H.P., so that considerable care was necessary to ensure that the appliances required for producing the air current, transmitting and absorbing the power, and for measuring the torque and speed should be capable of continuous working for a run of this magnitude.

The motor under test was erected on rails in a galvanised iron testing box 7 ft. by 6 ft. by 6 ft. high, one side of which communicated with the 4 ft. by 4 ft. air duct containing the fan, and the opposite side to a vertical discharge pipe 6 ft. by 4 ft. in cross section. The electrically driven fan for producing the air current was fixed to the inlet on the west wall of the testing house. In the 4 ft. by 4 ft. duct between the fan and the testing box a Pitot tube was fixed communicating with a water gauge inside the testing room, so that continuous observations of the velocity of the current could be made throughout the test. The other sides of the box were detachable for the purpose of erecting the engine, and were provided with windows for observing the motor. In Plate 1 is shown the testing box with the front side removed and a motor in position. The connections to the throttle and ignition were carried through the side of the box, so that during the test the testing box could be kept closed.

Estimation of the Speed of the Motor.—The speed was measured in two ways; one by the direct reading of a counter at stated intervals, and the other by an Elliott Speed Recorder worked from a magneto fixed to the shaft of the engine. The recorder is shown mounted at the top left-hand side of the switchboard in Plate 2. The time scale of the instrument was 12 in. per hour, and the pen indicated fluctuations of 0·5 per cent. of the mean speed.

Estimation of the Brake Horse Power.—The crank shaft of the motor was connected through a flexible coupling to the shaft of a 50 kilowatt generator mounted on knife edges, which formed a very sensitive dynamometer. The method of suspension of the generator on the knife edges will be clear from Plate 3. For this purpose the end bearings were provided with hardened steel rings which were in rolling contact with the steel knife edges as shown.

As this method of supporting a generator used as a dynamometer is apparently new, it may be stated that the difficulties experienced in constructing and setting up were quite small, and that the device gave no trouble whatever during the 24 hours' test. It was thought that the generator might move endways due to any small axial force on the armature, and to prevent this small rollers in ball bearings were fixed to the frame and in contact with the steel rings on the casing. It was found, however, that this precaution was needless, as there was no tendency for the machine to move endways.

The lever of the dynamometer is provided with a dash-pot for damping the oscillations, and a scale pan for the dead load, which was adjusted to the mean torque required.

For the purpose of recording the fluctuations of torque, the end of the lever arm was connected to a cast-iron pillar by means of a spiral spring, so that the varying tensions of this spring, recorded on a rotating drum, were a measure of the amount of the fluctuations. As the motion of the lever arm was limited to $\frac{1}{4}$ in. it was necessary to devise a multiplying gear of 6 to 1 to work the pen. For convenience this pen was fitted so that it should be in contact with the paper on the drum of the speed recorder. The whole arrangement is shown in Plate 4. By this means it was found possible to obtain a complete record of the fluctuations of speed and torque throughout the whole trial.

Absorption of the Power developed.—For this purpose special resistance mats were used, the form of which will be seen in Plate 2. By using a combination of these mats in parallel, adjusted by means of the switches on the board shown in Plate 2, it is possible to regulate the power absorbed to $\frac{1}{20}$th of a horse-power. These mats are not specially air-cooled in any way, and proved perfectly satisfactory for a 24 hours' run.

Tests with the Engine Tilted.—Under the conditions of the competition, tests of one hour duration had to be made with the shaft of the engine inclined at an angle of 15° to the horizontal, first with one end up and then the other. As the difficulties of using the generator with its axis inclined would have been considerable, a special water-cooled rope brake was made for the purpose of these tests. This brake was of the ordinary type, and consisted of a mild steel flanged disc specially fitted with spring balances and ball thrust bearings to work in an inclined position.

End Thrust.—To apply the required end thrust of 175 lbs. a bell-crank lever was mounted on a shaft in bearings bolted to the testing rails. The vertical arm of this lever was forked, and carried two $\frac{1}{2}$-in. Hoffman ball bearings, the outer collars of which fitted into a recess in the half of the flexible coupling nearest the engine. It may be noted that these bearings gave no sign of heating when running at 3,500 r.p.m. for 24 hours continuously.

The estimation of the petrol and oil was by direct weighing of the supply tanks before and after the trial. At the conclusion of the trial the water content of the jacket and radiator was measured, and the loss during the trial estimated. The engines were then taken down and weighed, and afterwards opened up and examined for signs of wear.

(iii) Report made to the Aerial League.

Captain R. A. Cave-Browne-Cave, R.N.,
Chairman of the Executive Committee of
The Aerial League of the British Empire,
Regent Street,
London, S.W.

November 8th, 1910.

Sir,

You will recollect that on October 19th, 1909, I wrote to you with regard to the very generous offer of Mr. Patrick Y. Alexander to provide a prize of £1,000 for a motor suitable for aeronautical purposes, informing you of the following resolution adopted by the Advisory Committee :—

> "The Advisory Committee for Aeronautics are prepared to "co-operate with the Aerial League in drawing up "Regulations for the Alexander Prize, and further, if "these Regulations, when drawn up, are satisfactory to "the Advisory Committee, they will undertake to carry "out the necessary tests on motors submitted for com-"petition, and to report to the Aerial League as to the "results."

As you are aware the Regulations for the competition were drawn up in November, 1909, by the Advisory Committee in conjunction with Mr. Alexander and the representatives of the Aerial League; and the Committee now have pleasure in forwarding herewith their report on the results of the trials of the engines received for test.

In forwarding this report the Committee desire to call attention to the fact that the essential conditions of the test were in no case fully complied with.

In any public announcement relating to the matter, the Committee request that this fact be definitely stated.

The engines were required to be delivered at the National Physical Laboratory not later than July 1st, 1910. Six engines were originally entered for the competition, but of these only three were delivered by the date named. These were entered by the following firms :—

Wolseley Tool and Motor Car Company, Limited.
Humber, Limited.
Green's Motor Patents Syndicate, Limited.

Particulars and results of the trials of these engines are given in the report. It will be seen that two of the engines failed to complete the 24 hours' run, and were not subjected to the further tests specified in the regulations. The third engine, entered by the Green Motor Patents Syndicate, completed a 24 hours' run, but it should be noted that the mean power maintained was 31·5 instead of 35 H.P.

Further tests as specified in the regulations were made on this engine, and the results are recorded in the report. With regard to these it is necessary to remark, with reference to Regulation 32, that the tests of the engine when tilted were made at 18 H.P. instead of at full load.

(Signed) R. T. Glazebrook,

Chairman.

Report on the Results of the Petrol Motor Trials in the Competition for the Alexander Prize.

Engine No. 1. *Competitors.*—The Wolseley Tool and Motor Car Company, Limited, Birmingham.

Makers.—The Wolseley Tool and Motor Car Company, Limited, Birmingham.

Description of Engine.

General.—This engine is one specially designed for aeroplanes. It has four cast-iron cylinders $3\frac{3}{4}$ ins. (95 mm.) bore, by $5\frac{1}{2}$ ins.* (140 mm.) stroke, mounted on an aluminium crank case. The water jackets are not cast solid with the cylinders, but are formed by bolting planished steel plates round the cylinders. The big ends of the connecting rods are of phosphor bronze, lined with white metal.

Valves.—These are underneath and on the same side of the motor, and are operated from the cam shaft by hardened steel tappets.

Carburettor.—The float chamber for the petrol supply is arranged to be concentric with the jet, so that the level of the petrol below the jet is constant for all usual inclinations of the engine.

Ignition.—The ignition is by Bosch high-tension magneto.

Cooling.—The cooling is effected by convection.

Lubrication.—This is of the forced type, by means of a gear pump.

Weight, as defined in Regulation 4.—242 lbs.

Results of Trials.

24 hours' Endurance Test.—After a preliminary run the test was commenced at 1.11 p.m. on September 12th. The engine ran very smoothly, doing 36 B.H.P. at 1,443 revolutions for two hours. It was then discovered that a copper oil pipe, leading from the pump to the oil-well, was leaking. The Company's engineer-in-charge decided not to stop, and, after 20 minutes, disconnected and blanked off this pipe while running. It appears, however, that this leak interfered with the oil supply to the bearings, for the engine began to run irregularly, and finally stopped at 4.13, when it was found that the white metal of one of the connecting-rod bearings had melted.

In accordance with clause 29 of the regulations, the motor was thereby disqualified. The representatives of the Company, however, expressed the desire that they might be allowed to repair the engine and that it might again undergo a 24 hours' trial. It was thought, in view of the cause of failure and the value of having as complete a test as possible of the engine, that it was desirable to accede to this request.

A new bearing was accordingly fitted, and another trial started at 9.50 a.m. on September 15th. The engine ran very well for four

* These figures were furnished by the makers.

hours, and then began to run irregularly. After five hours of the test a stop was made and a new sparking plug fitted to one cylinder. This was repeated after another hour's run, but without improving matters, the trouble being attributed to the faulty action of the radiator. After six hours of the test there was a stop of 50 minutes. The radiator was emptied and refilled. On re-starting, the engine ran for six hours and then failed. After three more short runs of 23 minutes, 92 minutes, and 38 minutes, it was observed that the cooling water was rapidly disappearing. The engineer-in-charge then decided to stop and examine the cylinders. On applying water at about 5 lbs. pressure to the jackets, it was found that the water was making its way into all four cylinders through cracks in their upper ends. The test was therefore discontinued after a total run of 17 hours 41 minutes, including seven stops aggregating 2 hours 18 minutes.

The cylinders were taken to the works on the next day, September 16th, and on September 17th the Wolseley Company withdrew from the competition.

Engine No 2. *Competitors.*—Humber Ltd., of Coventry.
Makers.—Humber Ltd., of Coventry.

Description of Engine.

General.—This engine is of the four-cylinder water-cooled type. The cylinders are of cast iron, 110 mm. bore, with a stroke of 120 mm. The cylinders are cast separately, and surrounded by copper water jackets.

Valves.—The valves are placed in the cylinder head and operated by concentric valve rods, the outer rod operating the inlet valve and the inner rod the exhaust. The cam operating the outer tappet is forked on the two sides of the cam operating the inlet.

The springs of the inlet valve are enclosed in cases over which is fitted the inlet pipe.

The exhaust valve springs are laminated cantilevers bolted on to bridges spanning two cylinders.

Carburettor.—The carburettor has a float chamber which, however, is not concentric with the jet. It is of the single jet type with automatic air control.

Ignition.—The ignition is by high tension magneto.

Cooling.—The circulation in the jackets is maintained by a water circulating pump driven from the same spindle as the magneto.

Lubrication.—The lubrication is forced ; a small pump draws oil from the base of the crank case and delivers it through jets inside the crank case, these being so placed that the oil squirts on to the big ends of the connecting rods and sprays from these round the engine.

Bearings.—Ball bearings are used for the five main bearings, and there is a thrust race at either end of the crank shaft to admit of the use of either a propeller or a tractor.

Weight, as defined in Regulation 4.—234 lbs.

Results of Trials.

24 hours' Endurance Test.—The erection of this engine was commenced on September 19th, and a preliminary run was made on September 21st. On September 22nd the assistant manager of the Company asked for permission to fix another radiator, as the one sent in with the engine was inadequate. He was informed that the Committee might take a serious view of such an alteration, and that the Company must make any alteration on their own responsibility. On September 23rd another radiator was fixed, which the competitors considered satisfactory, and, after a preliminary trial, the endurance test was commenced on September 26th, at 9.45 a.m.

After running for 16 minutes, as the ignition in one cylinder was not satisfactory, a stop of two minutes was made, and a new sparking plug fitted. The engine then ran steadily, doing 37 B.H.P. at 1,224 revolutions per minute for $11\frac{1}{4}$ hours, when the engine suddenly failed, and on external examination was seen to be completely wrecked, with one of the cylinders broken off. The only attention to the engine during this period was the addition of $12\frac{1}{2}$ pints of oil seven hours, and 50 pints eight hours, after the commencement of the trial. On the following day the engine was examined more in detail, and it was found that, in addition to the fractured cylinder, two connecting rods were buckled and the big end caps torn off, several holes were made in the crank casing, and the crank shaft was damaged. This accident, of course, brought the test of the Humber engine to a conclusion.

Engine No. 3. Competitors.—Green's Motor Patents Syndicate, Limited.

Makers.—The Aster Engineering Company, Limited, Wembley.

Description of Engine.

General.—This engine has four separately mounted cast steel cylinders, machined inside and out, of 105 mm. bore, with a stroke of 120 mm. The water jacket consists of a thin copper helmet, the joint with the cylinder at its lowest end being by a rubber ring fitting into a groove in the cylinder, so that the expansions of cylinder and helmet are independent. The cylinders are mounted on an aluminium crank case, the holding-down bolts being carried through to serve as supports for the crank-shaft bearings.

Valves.—The valves are of the mushroom spring-closed type, in detachable cases. Each valve is enclosed within a small dome, having an orifice through which the valve is actuated by the end of a short tappet pin. The cam shaft is carried in bearings in a small oil-tight horizontal casing, divided into halves, and is rotated by an encased vertical spindle situated in front of the engine. This

spindle is driven by a pair of worm-wheels from the crank shaft, The rocking levers are pivoted in extensions of the cam-shaft case, their striking ends being provided with adjusting screws, and the ends operated by the cams with rollers.

Carburettor.—This has no float chamber, and its action is independent of the inclination of the engine. It is of the single jet type, and has automatic air control.

Ignition.—The ignition is by high-tension magneto.

Cooling.—The engine is water-cooled, the circulation being effected by a gear pump.

Lubrication.—The main oil channel is cast solid with the crank case, and from this oil is forced by a small gear pump through leads at right angles communicating directly with each of the hollow columns through which the holding-down bolts pass, and thence to the main bearings and crank shaft, the latter being hollow. By this system the use of separate pipes is dispensed with.

Bearings.—The crank shaft is provided with bearings between each throw, and is slightly offset from the centre line of the cylinders. The ball race is designed to be used with either a propeller or a tractor.

Weight as defined in Regulation 4.—219 lbs.

Results of Trials.

24 hours' Endurance Test.—The erection of the engine was commenced on October 5th, but, owing to unavoidable delay, the preliminary run was not made until October 17th. The endurance test was commenced at 10.30 a.m. on October 18th. The engine did not run very satisfactorily during the first hour, owing to difficulties with the ignition, and after one hour's run a stop of ten minutes was made, during which new sparking plugs were fitted. On re-starting, the engine ran much better, and continued making approximately 31·5 B.H.P. at 1,213 revolutions per minute, until the completion of the 24 hours' run on October 19th. The only attention to the engine during this period was the addition of 42 pints of oil 17 hours after the commencement of the trial, and an additional 21 pints 22 hours after the commencement of the trial.

Other tests.—The maximum H.P. which could be maintained for seven minutes was determined on the same day without any overhauling of the engine, with the exception of grinding in the valves. The horse-power obtained was 36·4 at 1,390 revolutions per minute.

To test the effect of the gyroscopic action of the propeller a couple of 50 foot-pounds in a vertical plane was applied to the motor shaft for three minutes while the engine was running, but no effect on the speed and torque could be detected.

To determine whether the engine would work satifactorily when tilted about an axis transverse to the shaft, two runs of an hour

each were made on the engine when tilted at an angle of 15°, first one end, and then the other end, being uppermost. The competitors did not wish to run their engine at full load during this test, and maintained the B.H.P. at approximately 18 throughout both trials. The engine ran steadily in both cases, but it was noticed that the exhaust was decidedly smoky, apparently indicating over-lubrication.

The general steadiness and freedom from vibration of the engine when running were so marked that it was not considered necessary to test it when running and placed on elastic supports.

On the completion of the trials the engine was dismantled, and the working parts thoroughly examined. Very little wear could be detected in the crank shaft and connecting-rod bearings, and the state of the cylinders and valves appeared to be quite satisfactory. The ball races of the thrust bearing at the propeller end of the crank shaft were, however, considerably worn. In the crank-shaft bearings one of the aluminium caps was cracked right through for about one-third of its length. It was not certain that this crack had originated during the National Physical Laboratory tests, as there was some evidence that it existed before these trials began, but it appeared probable that the crack had become larger during the tests. In the case of one of the connecting rods, it was found that the sleeve inside the small end of the rod had rotated, so that the oil way to the pin was blocked up, and, further, the gudgeon pin had moved sideways and was rubbing against the sides of the cylinder.

Tabulated Results of the Trials.

The first line in the Table gives the figures laid down in the regulations for the competition.

A.—Endurance Tests.

Engine.	Gross run. h. m.	No. of stops.	Total Duration of stops. h. m.	Net run. h. m.	Weight of engine alone, lbs.	Moment of inertia of fly-wheel. ft. lb. units.	Mean speed r.p.m.	Mean B.H.P.	Total water carried in radiator, lbs.	Total water evaporated, lbs.	Petrol per B.H.P. per hour, lbs.	Oil per B.H.P. per hour, lbs.	Gross weight of engine with oil, fuel, cooling water and containing vessels for a 6-hour run, lbs.	Weight of engine alone per mean B.H.P., lbs.	Gross weight per B.H.P. for 6-hour run.
—	24 0	3	0 30	—	245	1·17	—	35	—	—	—	—	—	7	—
Wolseley	3 2	0	0 0	3 2	242	0·13	1445	36·2	32·0	6·0	0·632	0·082	453·2	6·69	12·52
,,	17 41	7	2 18	15 23	—	—	1420	34·8	32·0	40·0	0·613	0·115	457·2	6·95	13·14
Humber	11 32	1	0 2	11 30	234	0·61	1230	37·8	35·8	16·7	0·553	0,251	472·9	6·18	12·51
Green ...	24 0	1	0 10	23 50	219	0·26	1212	31·5	38·0	3·0	0·503	0·282	431·6	6·96	13·71

Remarks.—Humber Engine : $12\frac{1}{2}$ pints of oil added 7 hours after commencement of test, and 50 pints after 8 hours.
Green Engine : 42 pints of oil added 17 hours after commencement of test, and 21 pints after 22 hours.

Note.—The petrol was supplied to the Laboratory by Messrs. Carless, Capel & Leonard, and was described as their Standard Petrol of S.G. ·700.

B.—Maximum brake horse-power developed on run of seven minutes.

Engine.	Duration.	B.H.P.	Speed—revolutions per minute.	Remarks.
Wolseley...	—	—	—	—
Humber ...	—	—	—	—
Green ...	7 minutes	36·4	1390	The following readings were obtained with throttle fully open:— *Speed.* *B.H.P.* 1295 35·0 1350 35·8 1390 36·2 1470 37·1

C.—Test of Engine with moment of 50 ft.-lbs. applied to crank shaft in a vertical plane, to represent the gyroscopic action of the propeller in steering.

Engine.	Duration.	Remarks.
Wolseley	—	—
Humber	—	—
Green	3 minutes	No apparent effect on speed or torque.

D.—Trials run with the axis of the shaft inclined at an angle of 15° to the horizontal.

Engine.	Conditions.	Duration.	Remarks.
Wolseley ...	—	—	—
Humber ...	—	—	—
Green ...	Propeller end up ... " " down	1 hour 1 hour	In these tests the power was absorbed by a water-cooled rope brake. The H.P. developed was approximately 18 in each test. The engine ran quite smoothly in both trials.

Ease of starting—

No starting devices were supplied to any of the engines sent in, so that for the purpose of starting the engines the dynamo was connected to the Laboratory mains and used as a motor.

There was no difficulty in starting any of the engines tested, and they may be said to be equally good in this respect.

Security against fire—

Wolseley.—Nothing in design and construction to find fault with in this respect. No leak or accumulation of petrol observed.

Humber.—Reasonable security against fire. No leak or accumulation of petrol observed.

Green.—Reasonable security against fire. Radiator mounted on wood strips. No leak or accumulation of petrol observed.

Air resistance—

Wolseley.—Air resistance somewhat high, due to honeycomb form of radiator.

Humber.—Air resistance high, due to abnormal size of radiator.

Green.—Air resistance low, due to excellent design and distribution of radiator surfaces oblique to air current.

(iv.) Reproductions of the Autographic Records of the Speed and Torque during the 24 Hours' Trials.

The autographic records of speed and torque taken throughout the endurance tests are reproduced in Plates 5–7.

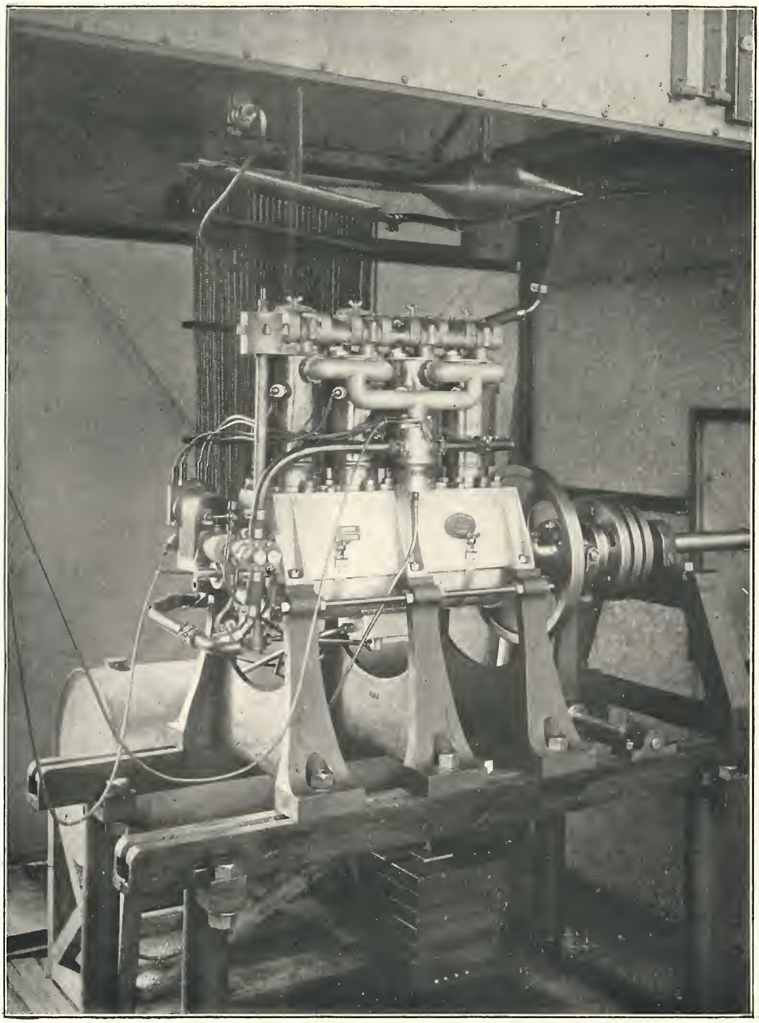
In the case of the Green and Humber engines, at the speeds at which the trials were made, there was more vibration of the torque pen than in the case of the Wolseley engine, which ran at a higher speed. This should be taken into account in interpreting the diagrams.

Some notes as to the possible causes of the fluctuations occurring are given with the diagrams. These are taken from the test sheets and represent the view taken by the observer at the time, but it must not be assumed that in every case the supposed cause was the true or only cause of the variations. The notes are reproduced in the hope that they may be of some assistance in the interpretation of the records.

The field of the generator was excited from the bus bars of the Laboratory, which were occasionally subject to changes in voltage due to throwing off machines. A few momentary fluctuations on the speed and torque curves due to this cause will be found on the diagrams, and are indicated in the notes.

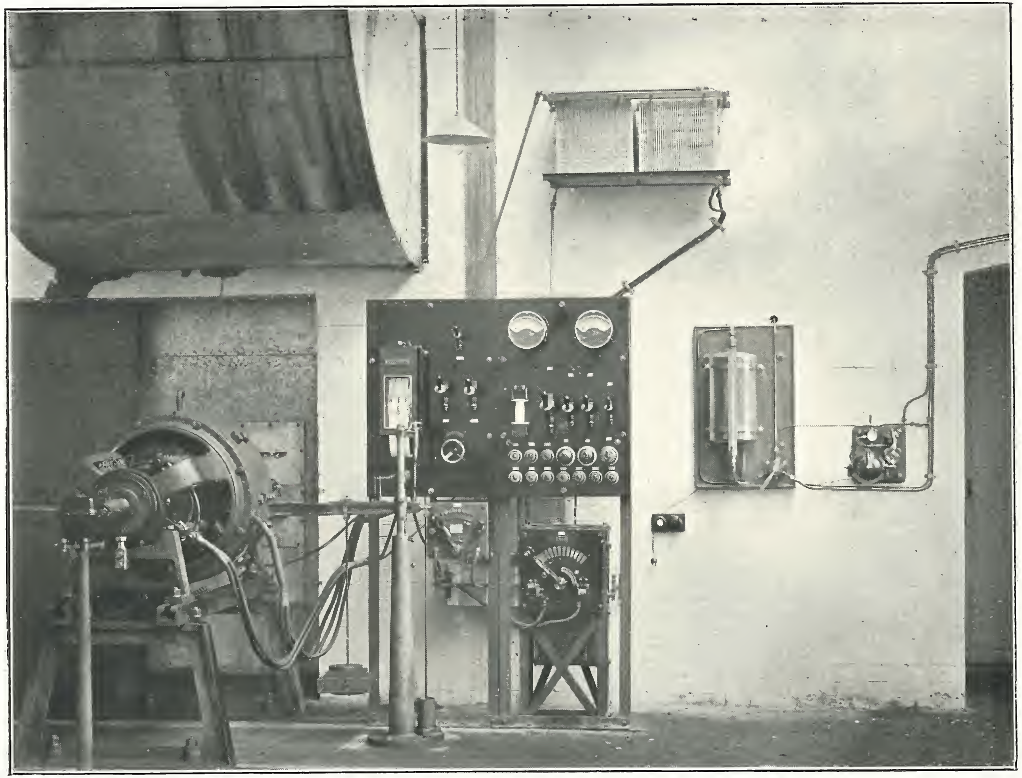
A line is drawn on each diagram to indicate the value of the torque, at the mean speed, corresponding to 35 H.P.

Plate 1.

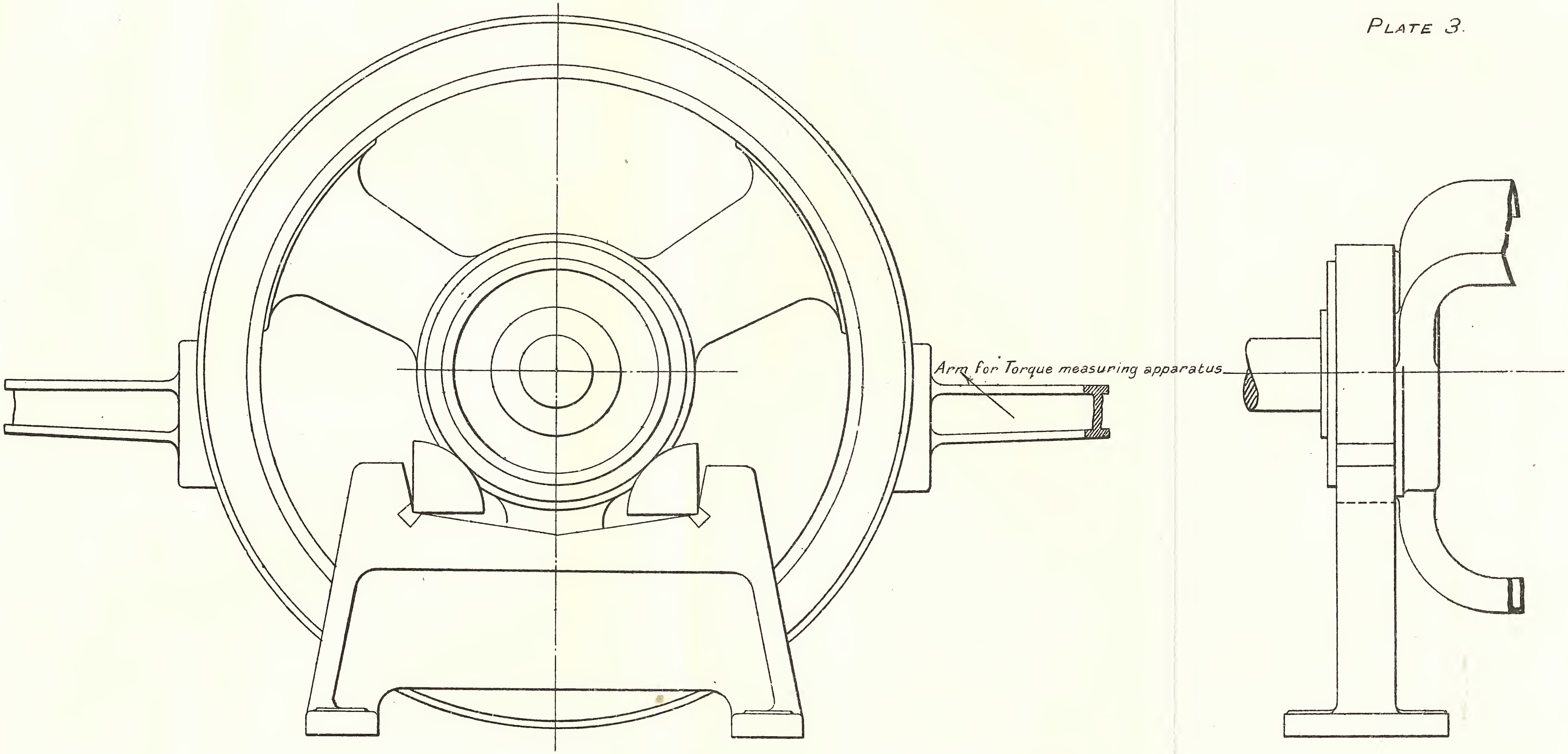


Testing Rails with Petrol Motor in Position.

Plate 2.



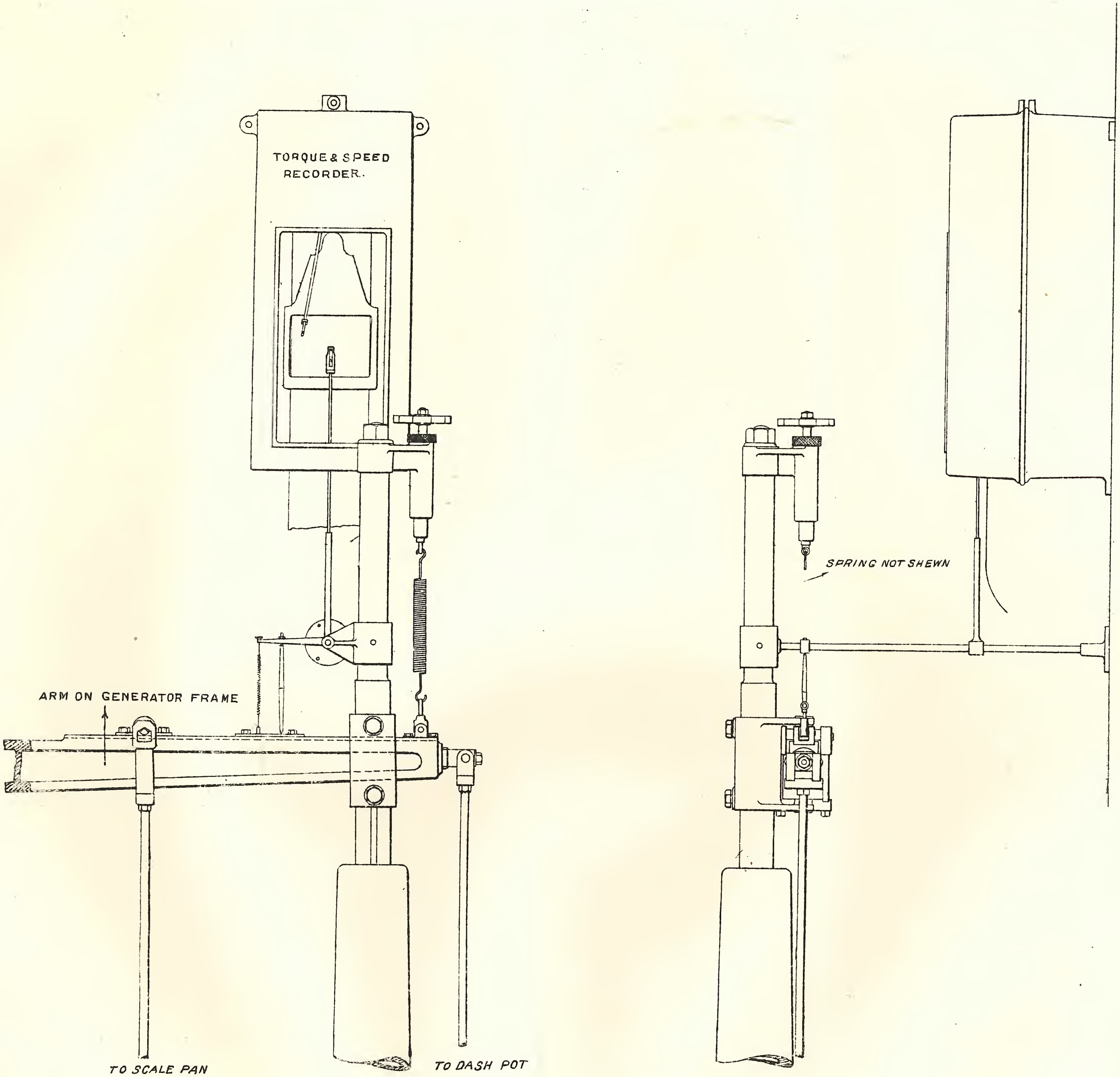
50 Kilowatt Recording Dynamometer.



KNIFE EDGE SUPPORT FOR GENERATOR FRAME

MOTOR TESTING DYNAMOMETER.

Weller & Graham, L^td Litho, London



RECORDING APPARATUS.

MOTOR TESTING DYNAMOMETER.

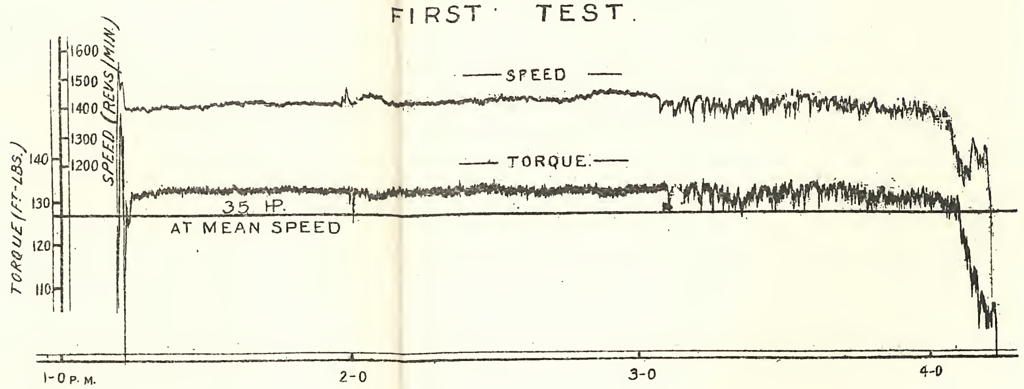
4455.

Weller & Graham. Ltd. Litho, London.

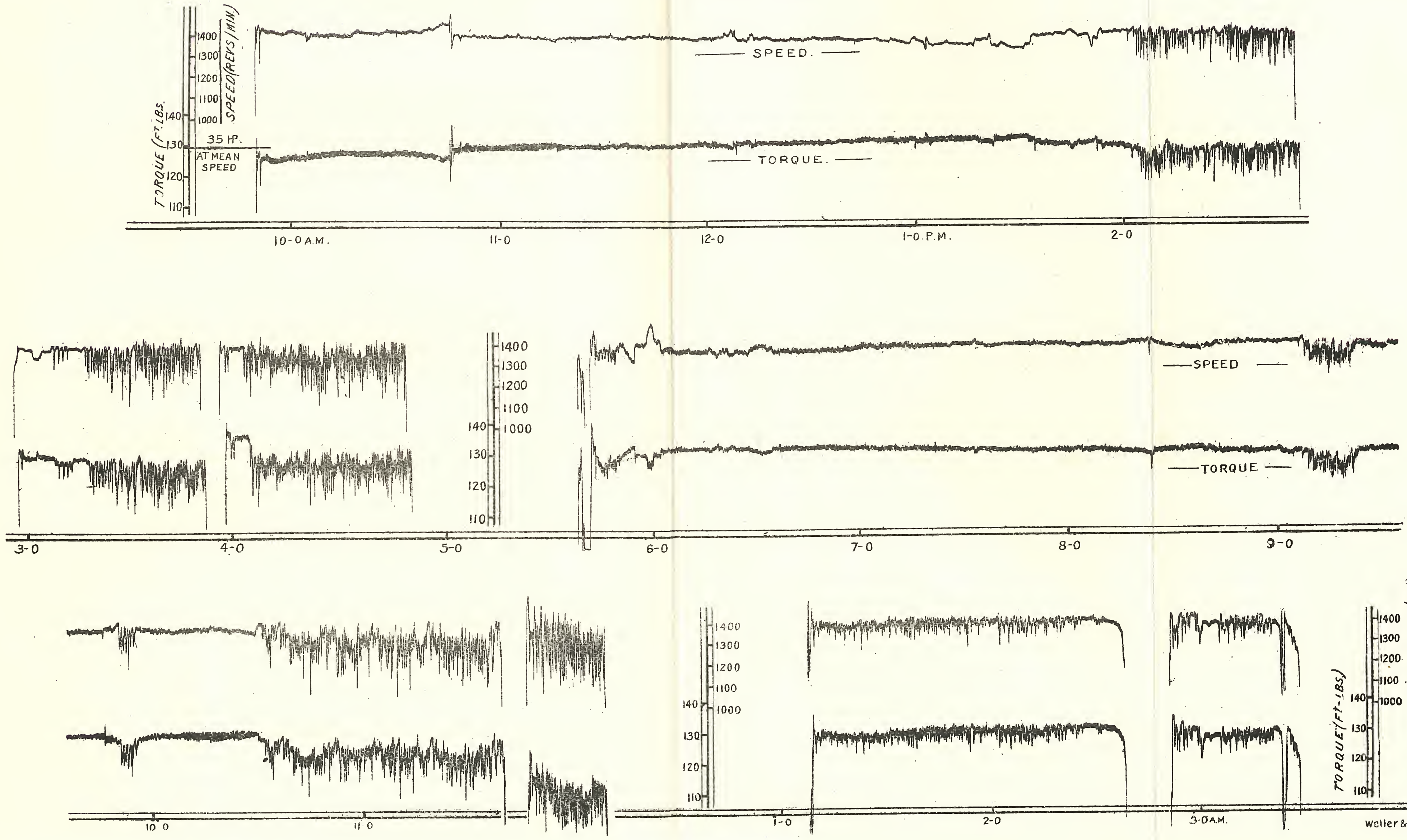
ENGINE No. 1.

WOLSELEY TOOL & MOTOR CAR CO.

FIRST TEST.



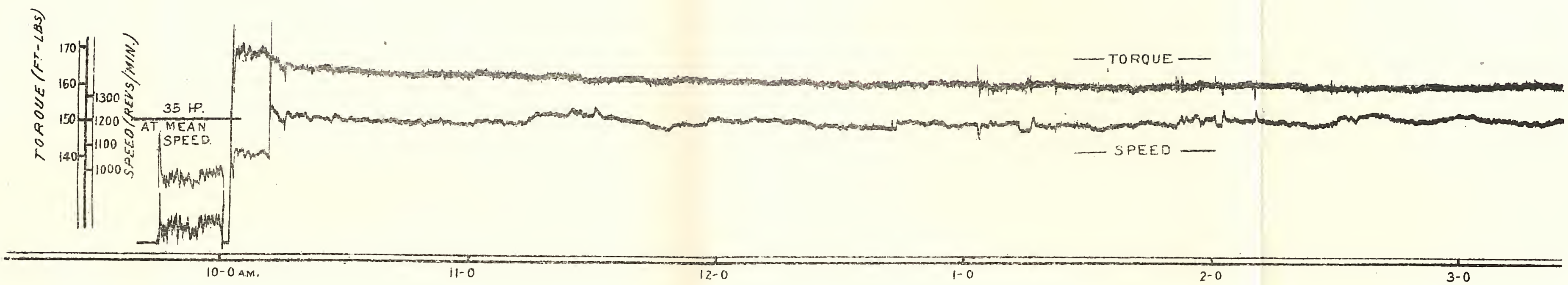
SECOND TEST



Waller & Graham, L.td Litho. London

ENGINE No. 2.
HUMBER LTD

Plate 6.



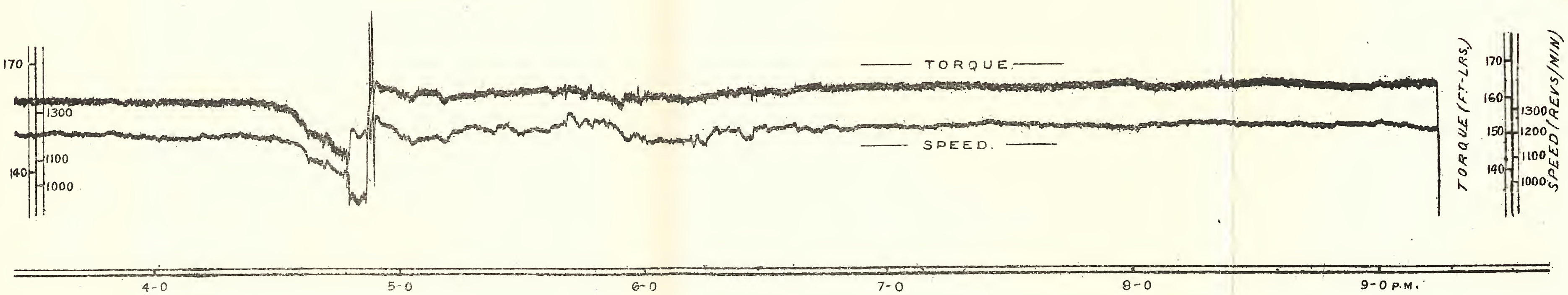


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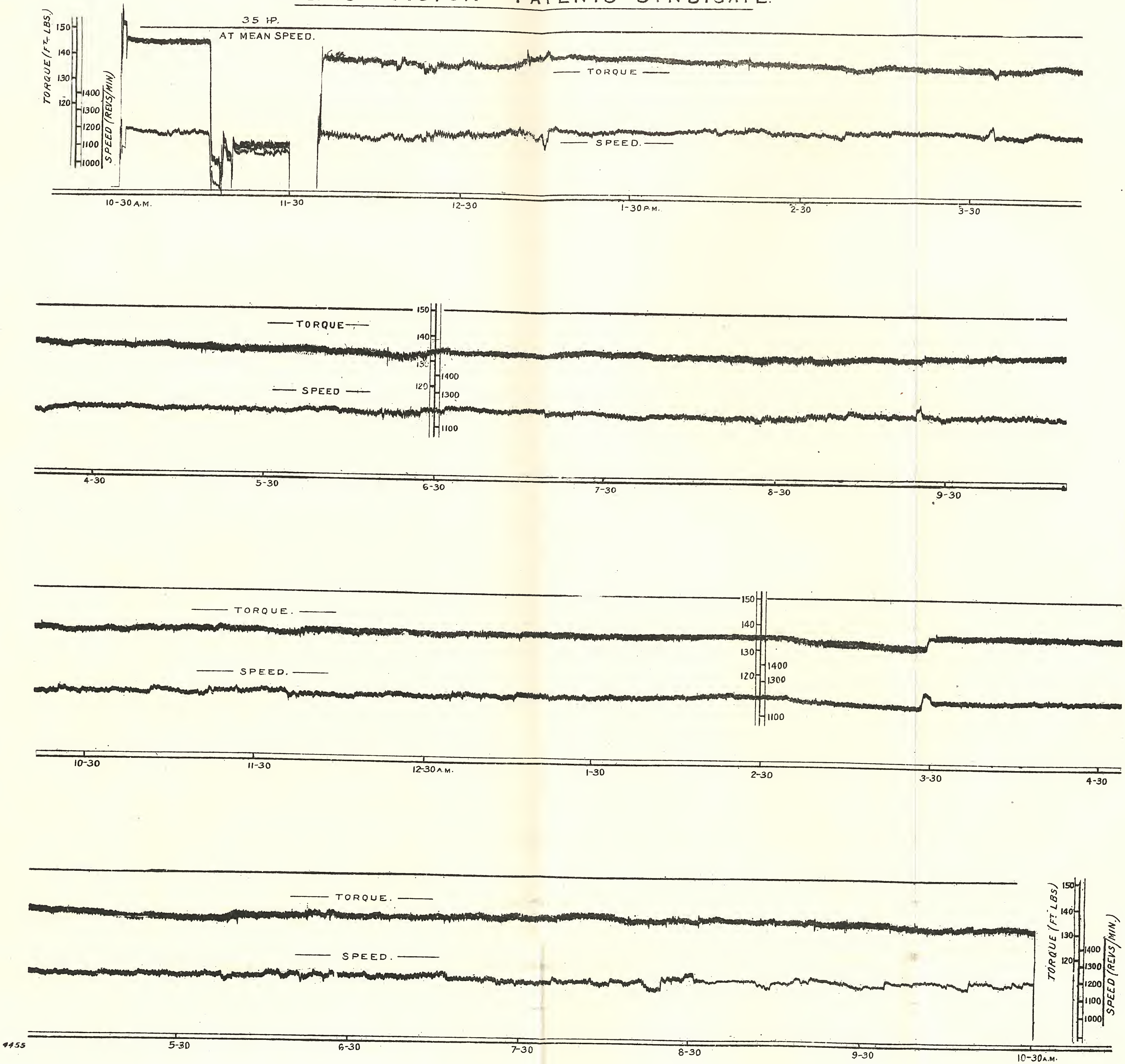
Plate 7.

Engine No. 3

Green's Motor Patents Syndicate.



4455

NOTES RELATING TO PLATES 5, 6, 7.

Wolseley Engine.—First Test.

1.11	p.m.	Start.
2.0	„	Kick on recorder chart due to change of voltage on bus bars.
3.5	„	Oil pipe in circulating system cracked and leaking.
4.13	„	White metal in connecting rod end melted out. End of trial.

Wolseley Engine.—Second Test.

9.50	a.m.	Start.
10.45	„	Regulation of load at dynamometer switchboard.
12.9	p.m.	Irregularities due to change of voltage on bus bars.
1.34 to 1.52	„	Regulation of load at dynamometer switchboard.
2.5 to 2.50	„	Probably misfiring.
2.20	„	Two pints of water added to radiator.
2.50	„	Stop. One sparking plug No. 3 found broken, Nos. 3 and 4 replaced.
2.56	„	Start.
3.15 to 3.50	„	Probably misfiring.
3.50	„	Stop. New sparking plugs in Nos. 3 and 4. Magneto contacts cleaned.
3.55 to 4.50	„	Probably misfiring.
4.50	„	Stop. Magneto and sparking plugs Nos. 3 and 4 examined. Radiator connection leaking. Repaired. Water level in radiator at restart made the same as at stop.
5.39	„	Start.
8.30	„	Two pints of water added to radiator.
9.5 to 9.20	„	Probably pre-igniting.
9.50	„	Probably pre-igniting.
9.55	„	Two pints of water added to radiator.
10.30 to 11.40	„	Misfiring in cylinders 3 and 4.
10.45	„	Two pints of water added to radiator.
11.40	„	Stop. Replaced plugs Nos. 3 and 4.
11.47	„	Start. Misfiring.
12.10	a.m.	Stop. Inlet valve No. 3 ground in. Repairs to carburettor due to accident in removing jet.
1.9	„	Start.
2.41	„	Stop. Nine pints of water added to radiator.
2.53	„	Start.
3.20	„	Nine pints of water added to radiator.
3.31	„	Stop. Engine examined. Two cylinder heads cracked, allowing hot gases to leak into water jacket. End of trial.

Humber Engine.

9.45	a.m.	Start. No. 2 cylinder not working.
10.1	„	Stop. New sparking plug in No. 2.
10.3	„	Start.
10.12	„	Regulation at switch board to allow increased speed.
4.49	p.m.	12½ pints of oil added without stopping.
5.40	„	50 pints of oil added without stopping.
9.18	„	Cylinder cracked. End of Test.

Green Engine.

10.31	a.m.	Start.
11.2	„	One cylinder probably not working.
11.30	„	Stop. Four new sparking plugs fitted.
11.40	„	Start.
3.27	„	42 pints of oil added without stopping.
8.20	„	21 pints of oil added without stopping.
10.31	„	End of trial.

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